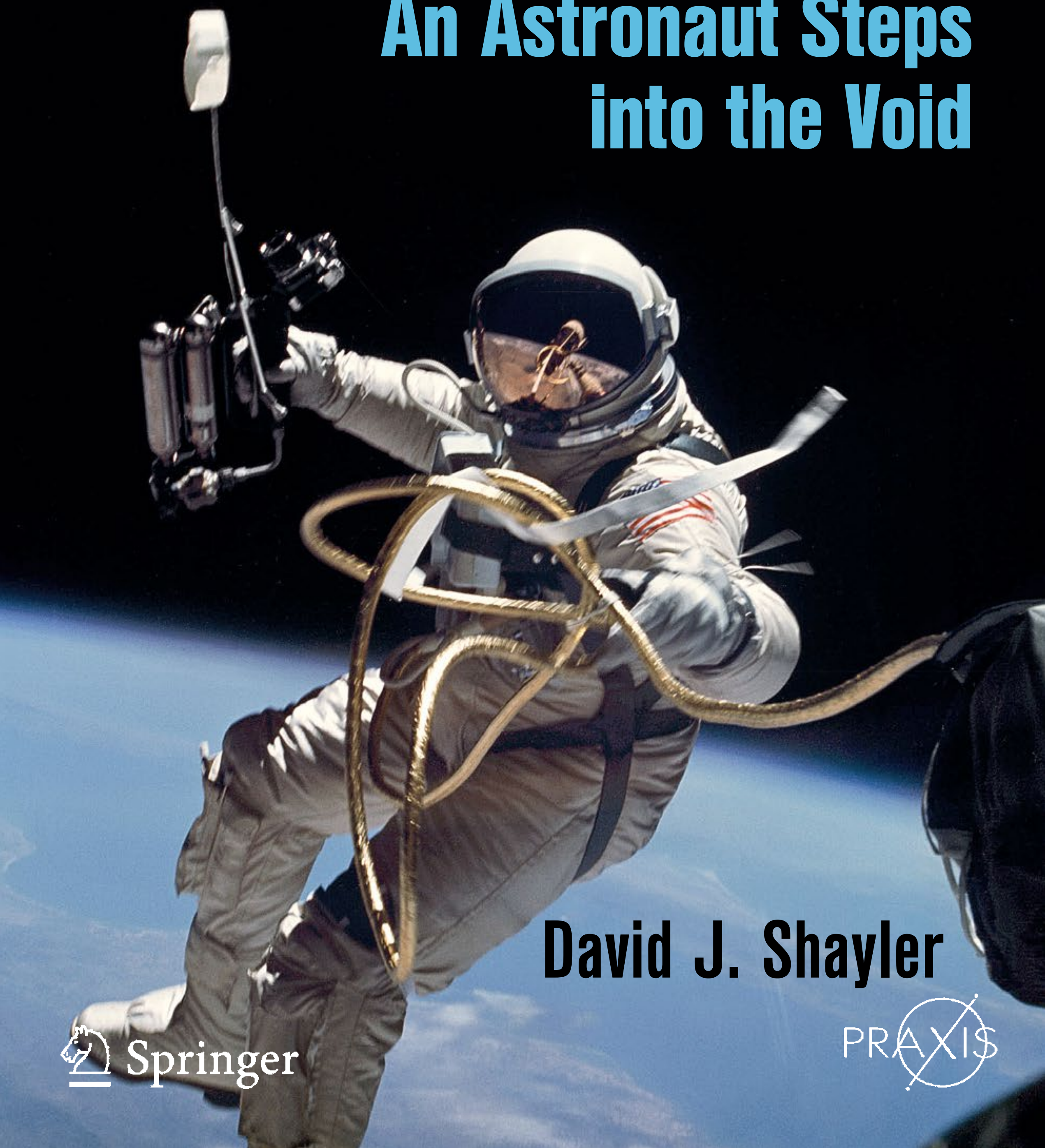
PIONEERS IN EARLY SPACEFLIGHT

GEMINI 4

An Astronaut Steps into the Void



David J. Shayler

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COVER IMAGE CAPTIONS:
(Front Cover): A classic image from Gemini 4. Pilot Edward H. White II becomes the second man and first American to walk in space, June 3, 1965.
(Back Cover) [Top] The Gemini 4 prime crew wearing full G-4C pressure suits. Pilot Edward H. White II (left) is accompanied by Command Pilot James A. McDivitt (right). [Courtesy Ed Hengeveld]. [Bottom] The front cover design for the next book in this series: Gemini 5, Eight Days in Space or Bust.

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Contents

Author's Preface

My earliest recollection of watching 'an astronaut walk in space' comes from fond childhood memories. Six years before I became hooked on real human spaceflight and the careers of those who flew the missions, I was an ardent fan of Colonel Steve Zodiac and his crew on Gerry Anderson's *Fireball XL-5*, as they patrolled Sector 25 in the outer reaches of space. Strange aliens, hostile planets and space criminals added to exciting adventures of this heroic crew. Yes, it was only a TV show and the main characters were marionette puppets, but it left an impression on the seven-year-old me. The 'walking in space' bit was memorable in that the *XL-5* crew simply popped an oxygen pill in their mouths and donned a jet-pack or used a space scooter to venture outside their spacecraft. Ah! The simple, innocent magic of childhood.

Of course a few years later, the teenage me had learned the realities of space flight from factual articles in boys' comics and adventure stories, in that a pressure garment was a necessary piece of kit to venture outside a spacecraft – a spacesuit. Then, when later reading about what the Apollo astronauts were to attempt in walking on the Moon, I also learned about the spacewalks and spacesuits of an earlier program called Gemini, a series of flights which had passed me by in favor of new TV heroes flying the *Thunderbirds* machines under the guise of *International Rescue*. Those vivid images from childhood of spacewalking adventures sowed the seeds for my life-long interest in the techniques and hardware of walking in space, formally called Extra-Vehicular Activity, or EVA.

Today, half-a-century later, science fiction has given way to a keen interest in science fact, the development of EVA techniques and the history of operations. In the ensuing years, I have penned a number of articles, delivered numerous presentations and written several titles focused around EVA and pressure suits. So when I embarked on this recollection of the Gemini missions, it not only enabled me to fill in the gaps I had missed as they happened, as a 10–11 year old, but also allowed me look deeper into the pioneering EVAs and pressure suits used on those missions than I was able to do for my earlier work on Gemini [*Gemini: Steps to the Moon*] in 2001.

The Soviets may have scored another headline-grabbing space first when cosmonaut Alexei Leonov conducted the world's first spacewalk in March 1965, but it was the American Gemini astronauts who took the next step and addressed the challenges of attempting to work and survive in open space. They were the ones to meet and overcome some of the basic problems facing anyone wearing a bulky pressure garment and trying to complete productive tasks in a microgravity environment, with huge variations in temperatures, light and pressure, and always with defined time limits. Today, though never taken for granted, EVA is seen as an operational necessity for space station operations, for the repair and upgrading of satellites and vast space structures, and is famous for the human exploration on the Moon, with plans to return there and, one day, in the not too distant future, to explore the asteroids and the planet Mars.

Despite all the technology, advancement and complexity of modern day EVAs, each can be traced back to that pioneering first step outside a spacecraft by Leonov, and to the Gemini EVAs where humans first realized that leaving the spacecraft and working outside might not be as straightforward as first thought. Lessons learned from Gemini have had direct application over the decades beyond the historic Apollo lunar moonwalks, to dramatic satellite repairs and servicing missions on the Shuttle and on to space station maintenance. For the Americans, their EVA heritage can be traced back to a huge team effort over many years, but in particular to one flight and one man – Gemini 4 and Ed White.

When choosing a topic for the cover image for this book, there could really only be one: the dramatic EVA footage of Ed White outside Gemini 4, taken by his commander, Jim McDivitt, from inside the unpressurized spacecraft. Over five decades after the event, McDivitt's shots of White's walk in space on June 3, 1965, remain iconic images of the early years of the space program, somewhat at odds with the fact that White's photogenic EVA was not the first spacewalk in history. Unfortunately for Alexei Leonov, he had to rely on primitive automated TV and movie imagery, as his commander, Pavel Belyayev, was still inside the pressurized compartment of Voskhod 2 without a suitable viewing window to record the event with better cameras.

Photographically crisper than the grainy images of Leonov's historic first EVA, the Gemini 4 images, together with the Apollo 8 image of 'Earth rise' and the Apollo 11 image of Edwin 'Buzz' Aldrin standing on the Sea of Tranquility, are key milestones not only in human space exploration but also in photographic history and technological achievement. The fact that all these images are American is also interesting, because most of the 'space firsts' of the early years of the space age were achieved by the Soviets. However, the secretive and hidden nature of the Soviet program was the direct opposite of the openness of most of the American effort to conquer space. That secrecy, coupled with the apparent ease with which the Americans began to succeed, ironically led to problems in 'selling the idea of human spaceflight' beyond the Moon in both nations.

But the cover image tells only part of the story of Gemini 4; specifically, that of the first American to leave the safe confines of his spacecraft and venture out, 'floating' free in the weightless environment of space. Well, sort of. In truth, the forces of gravity governed every move and action, so 'spacewalking' and even 'space floating' are not really accurate descriptions. A better term would be 'space falling' in microgravity, but we have generally come to accept the terms 'zero-g', 'spacewalking', and 'weightlessness' over the last fifty or so years.

Gemini 4 was far more than just the single, 20-minute EVA early in a mission of over 97 hours, though that is what the mission is mostly remembered for. As the second manned Gemini to fly, this mission would also begin to extend America's space endurance record, prior to the far more complex Apollo lunar missions. At the end of March 1965, America's longest space flight experience for Gemini was only three orbits (five hours), from Gemini 3 that month. Indeed, the longest American spaceflight at all was just 22 orbits (36 hours) on the final Mercury flight, MA-9, in May 1963. Gemini 4 alone would push this to an impressive four days, effectively trebling the total American human spaceflight experience that had been accumulated in the six Mercury missions and one previous Gemini mission combined. The EVA itself was not exactly thrown in for good measure, but was included in the flight plan to fulfill an early objective of the program, and partly in response to the historic first snatched by the Soviets a few weeks earlier. But that was not all. Gemini 4 also paved the way for the more complex space rendezvous and proximity operations that would be necessary for project Apollo to reach the Moon using the Lunar Orbital Rendezvous (LOR) technique chosen. Though the exercise on Gemini 4 did not exactly go as planned, it was a step in the right direction pending the more dedicated missions to follow.

Another 'objective' for the mission is often overlooked: that of learning to live and work in the confinement of the spacecraft for four days, while also conducting a number of important observations from orbit and operating a range of experiments, thus expanding the scientific return from the flight.

The pioneering missions of Project Mercury and Gemini 3, and indeed those by the Soviets under the Vostok and Voskhod program, had established the fact that humans could survive and endure the launch, orbital flight, and re-entry and landing either on land or water, and could perform some useful smaller experiments and observations while on orbit. For the Americans, Gemini 4 became the flight with which they also began to learn the skills of truly exploring space. The first small step towards what would eventually become more routine operations, Gemini 4 gave NASA experience and confidence, but also early warnings that the skills required for space exploration would not be easily mastered. The mission was another step in the right direction and one from which their experience grew, to the point that today, fifty years later, ISS crews are routinely completing expeditions on the station of about four to six months.

This second volume in the series reveals the four days spent onboard Gemini 4, its buildup and aftermath. It is also about what the crew accomplished after they closed the hatch on America's first spacewalk and opened a new door of opportunity on the road to long-duration spaceflight.

When compiling the draft for this book, I became aware of the huge amount of information gleaned from flying the four-day Gemini 4 compared to the three short orbits of Gemini 3. This significant change in operations for those involved in the program at this time must have been dramatic, suddenly switching from short, relatively 'simple' missions to far more demanding activities with each flight, with little time between them and no time to lick any wounds or celebrate their successes before the next flight was on the pad. There was also a dramatic difference in the flight activities between the first four orbits of Gemini 4 and the entire mission of Gemini 3. Then there is the stark comparison to the rest of the Gemini 4 flight, with four days of paced activities, which at times must have seemed quite mundane to the press and presented a different challenge to the astronauts and flight controllers. These very different levels of intensity on this flight are the reason I have focused on the detail of those first four orbits or approximately six hours, summarized the remaining 58 orbits (90 hours) orbit by orbit, and then returned in some detail to the re-entry, recovery and post-flight activities.

The story of Gemini 4 did not end with the recovery and early analysis of its achievements and failures, however, nor with the two weeks of hectic post-flight activities for the crew. With Gemini 5 just weeks away, the lessons learnt from Gemini 4 had to be applied quickly in order to understand fully what was to come for those who would fly or control the next mission. That mission, in turn, was but a stepping stone to the ultimate goal of a 14-day flight, and that was without adding any docking activities or further EVA. Those activities were planned for the later missions. For this book, an in-depth analysis of Gemini 4's systems and procedures has not been included. Instead, it is carried over to the opening chapter of the Gemini 5 book. That mission would see the focus of the Gemini program intensify as the era of Apollo drew ever closer.

This is the broader plan for this series of books covering the 12 Gemini missions. The current mission was but a step in the overall success of the program and, for many reasons, was key to the planning and operations on next flight in the series. Each book can be read as a standalone title, but from Gemini 4, where the testing of the Gemini system really reached a pinnacle before the operational story took over, the ongoing evolution will be woven through the forthcoming titles. These books, therefore, do not replace, but only expand and supplement my original work on this intriguing program back in 2001.

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Acknowledgements

For this, the second in the series of nine books on the American Gemini missions, the bulk of the acknowledgements remain very similar to those quoted in the first volume, *Gemini Flies: Unmanned Flights and the First Manned Mission* [Springer-Praxis 2018]. As with any work of this magnitude, an on-going network of contacts and sources is a vital resource and, as with every spaceflight, there is a huge support team on the ground. It is the same for the production of the finished book, with a huge infrastructure behind the scenes for each project, from the initial acceptance of the original proposal, through editing the draft manuscript, to layout, production and marketing.

Specifically for this project, I appreciate the continued support of my brother and Project Editor Mike Shayler, for his professionalism in seeing yet another of my projects through the quagmire of editorial and production levels. For Mike to convert my… unique scribblings and arrive at what you see here is no less than wordsmith alchemy.

Very special thanks are extended to former NASA flight controllers Manfred 'Dutch' von Ehrenfried for his excellent Foreword, and Jerry Bostick in recalling the early days of the NASA Mission Control room.

An appreciation is also given for the assistance of the family of Norman Shyken (1932–1978) of McDonnell Douglas Aircraft. Norman helped coordinate the work involved in the Gemini extra-vehicular activity program and was later an unsuccessful short-listed candidate for the NASA 1966 (Group 5) astronaut selection.

Special thanks are due to Ed Hengeveld and Joachim Becker of *SpaceFacts.de* who continue to find those rare images which just have to be included in the book; to my good friend and colleague Colin Burgess, for copies of contemporary Australian newspaper articles from his own collection; to David Harland for the supply of obscure Gemini documents; and to Michael Cassutt for his pioneering research into the workings, myths and realities of the NASA Astronaut Office at JSC. Thanks also to Colin Mackellar and Hamish Lindsey in Australia, for their work on detailing the history of Australian space tracking sites.

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Once again, the majority of images used in this book originate from NASA, various military service organisations, the author's own collection and those credited in the individual captions, unless specifically stated. However, despite extensive searches, I have been unable to determine the exact origin of some of the images. I would therefore welcome any input to enable me to credit the appropriate source.

Clive Horwood of Praxis Books enthusiastically continues to support and encourage his authors to expand the space science series. Thanks also to Jim Wilkie for yet another impressive cover design, and to Maury Solomon and her assistant Hannah Kaufman at Springer New York for supporting the project and guiding it though the acceptance process.

Finally, thanks go to my mother, Jean Shayler, who continues to be enthusiastic about each project we embark on; to my biggest supporter, my wife Bel, who looks forward to those promised river cruises we will take when I finally 'retire' from writing; and to a very patient and energetic German Shepherd named Shado, who has managed find a new play area in a local field to chase around in (him, not me!) before I get lost in my next project.

To all, a very large thank you.

Dedication

To the crew of Gemini 4
James A. McDivitt
&
Edward H. White II (1930–1967)

As the previous volume in this series was being completed, the news was announced of the sad loss of the Pilot of Gemini 3 & Command Pilot of Gemini 10

John W. Young (1930–2018)

Then, as this current volume was being prepared, a further blow to the space community was felt with the loss of former Gemini 10 Back Up Command Pilot and later Apollo & Skylab crewmember

Alan L. Bean (1932–2018)

This book is also dedicated to their memory and achievements.

Foreword

The space race was heating up in the early 1960s. President Kennedy's famous speech in September of 1962 dropped the official flag on the start of the formal race to the Moon. Sputnik and Yuri Gagarin's flight were just the Soviet equivalent of a teenager revving up the engines of his hot rod at the starting line while glancing over to his competitor; the American kid. But the challenge was accepted, even though the kid's car was a jalopy in comparison.

A couple of years after Gagarin, in 1963, the Americans completed Project Mercury, but the Soviets began launching people into space only days apart; even a woman! By 1964, it became a race between the two-man Gemini spacecraft and the three-man Voskhod spacecraft. Then, by 1965, it became a race between who could accomplish a rendezvous and who could conduct an extra-vehicular activity (EVA), now known by the public as a "spacewalk."

On March 18, 1965, the Voskhod 2 spacecraft carrying Pavel Belyayev and Alexei Leonov was launched. On the second orbit, Leonov conducted the first EVA. It was only short, as it was plagued with serious problems not publicly known at the time, even in the Soviet Union. Many years later, I had the opportunity to meet with Leonov personally and discuss his suit problems. At this point in the race, the Soviets beat us to this milestone, just as they had beaten us to others in the race to the Moon.

Less than a week later, on March 23, 1965, the Americans proved that the Gemini spacecraft was a great design, as was the Titan II launch vehicle. Gus Grissom and John Young checked out the spacecraft's new capabilities over three orbits. The following week, the Manned Spacecraft Center Director, Robert Gilruth, convened a group of experts and decided that the next Gemini flight would conduct a full EVA; not just standing up on the seat with the hatch open, as was the original plan. This would require a new piece of equipment called the "Hand-Held Maneuvering Unit" (the HHMU, aka the "jet gun") and involved more planning as well as mission rules should anything go wrong.

GT-4 was to be a mission of relative endurance, as it would be longer than all of our previous manned flights combined. It was also the first mission flown from the new Houston Mission Control Center. Due to the long mission duration, the MCC would require three shifts of flight controllers. The Red Team Flight Director was Chris Kraft, the White Team Flight Director was Gene Kranz (his first mission as a Flight Director) and the Blue Team Flight Director was John Hodge.

Even before Leonov's EVA, Ed White had been training for an EVA of his own. It wasn't until after GT-3's successful flight that Chris Kraft advised Gene Kranz, Head of the Flight Control Operations Branch, that an EVA was being considered and that Gene should secretly begin developing the mission rules. This activity began in early April and a special subset of Mission Rules, called Plan X, included a rendezvous with the Titan booster's second stage as well as the EVA.

(left) Manfred 'Dutch' von Ehrenfried in 1961. Four years later, he served as Assistant Flight Director (Red Team) for Gemini 4. (right) 'Dutch' von Ehrenfried in 2009. [Courtesy Manfred von Ehrenfried].

While I was the coordinator for the main Mission Rules document, I didn't get the word about the EVA until I was asked to attend a secret meeting with the EVA team. One day in May, I attended a meeting with Ed White, General Bollander from NASA Headquarters, a Crew Systems engineer and another man from the Engineering Department.

We went over the Plan X rules and I reported the results back to Kranz. On May 10, Kranz called in all of the Capcom flight controllers who were deploying to the remote sites around the world and gave them the sealed Plan X package, with instructions not to open them until they got instructions from him. If no instruction was given, they had to be returned unopened. On or about May 27, the go for EVA came down from NASA Headquarters and all the flight controllers were advised and thoroughly briefed.

On June 3, 1965, only 41 days after Grissom and Young had landed in Gemini 3 on March 23, Jim McDivitt and Ed White were launched on Gemini 4. After orbit insertion, the initial attempt to station-keep with the Titan II second stage did not go well. McDivitt's attempt to maneuver closer to the booster resulted in a retrograde maneuver which lowered the Gemini's orbit slightly and increased its speed and separation. The counterintuitive nature of orbital mechanics became obvious. The attempt was cancelled.

As Assistant Flight Director to Christopher Kraft, I was standing next to him during the EVA. Having worked on the Mission Rules, I knew what emergencies could arise and what our available options were for every perceived contingency. On the third orbit, the 'Go/No Go' was given by the Carnarvon Capcom. McDivitt and White began their decompression and suit checks and were given a Go for EVA by Gus Grissom, the MCC Capcom.

The control center was very quiet as all the flight controllers listened to the communications between McDivitt, White and Grissom. White maneuvered away from the spacecraft, while McDivitt took some now-famous photos, one of which hangs on my office wall signed by White. His signature is still vivid after over a half-century, while the sunlight has faded the color photograph.

As the orbit approached darkness, Kraft told Grissom to get White back in, which was relayed to McDivitt. White was having too good a time to come back in and had to be ordered in by the MCC, though this was relayed to White as more of a coaxing; "Come on, let's get back in here before it gets dark," said McDivitt. White responded, "It's the saddest moment of my life. I'm coming."

As races are often measured in small increments, Ed White's EVA would last twice as long as Alexei Leonov's. He would go out more than twice as far and the mission lasted four days vs. one. Like Leonov, Ed White also had some difficulty getting back in and closing the hatch. Fortunately, Jim McDivitt had previously experienced hatch problems in training and knew how to handle the situation.

This book will document one of the great missions of America's space program. It was a time when we realized that we had a space program that was capable of going to the Moon. We could do "the other things, not because they are easy, but because they are hard."

Manfred 'Dutch' von Ehrenfried
Red Team Assistant Flight Director
Gemini-Titan 4

Acronyms and Abbreviations

Distances used in the text (As per The Concise Oxford Dictionary, New Edition, 2003).

Mile (or statute mile)
A unit of linear measurement equal to 1,760 yards or 5,280 feet (1.609 kilometers).

Nautical Mile (or sea mile)
A unit of measurement of approximately 2,025 yards or 6,075 feet (1,852 meters).

Kilometer
A metric unit of measurement equal to 1,000 meters (approximately 0.62 miles).

Apogee
A point in an orbit where an object (in this case a spacecraft) is furthest from the Earth (the opposite of perigee).

Perigee
A point in an orbit where an object (in this case a spacecraft) is nearest to the Earth (the opposite of apogee).

Orbit
The path of a spacecraft under the influence of gravitational forces beginning and ending at a fixed point in space after completing 360 degrees of travel around a celestial body, in this case Earth. This, for clarity, is the term used in these books.

Revolution
A circuit of a celestial body, in this case the Earth, which begins and ends at a fixed point on the surface of that body. As Earth is *revolving* in the same direction as the trajectory of the orbital spacecraft (Gemini), this point in space moves further ahead, requiring the spacecraft to 'catch-up' and resulting in more than 360 degrees of travel in an orbit. Therefore, a revolution is about six minutes longer than an orbit. In the early days of the space program, the number of circuits around the Earth was originally given in orbits. Then Mission Control started to quote revolutions, which became confusing to the general public, so they switched back again. Today, the word 'orbit' continues to be the most commonly used term in recording the number of circuits of a spacecraft around the Earth (or other celestial body).

A word on Zero-g, or Weightlessness, or Microgravity
A long-term misnomer in space exploration concerns the terms 'zero-g' or 'weightlessness.' The motions of astronauts floating in space were described (for clarity, but incorrectly) as being in zero-gravity (or zero-g) or having no weight (weightlessness). In fact, there are gravitational forces at play in space and a more correct description would be 'microgravity', as those forces are there but are mostly negated by orbital motion. As an object (spacecraft) travels in the cosmos, apparently following a straight-line, it is also 'pulled' by the gravitational forces of celestial bodies. A spacecraft circulating around a celestial body is still being pulled towards it by gravity, but if that spacecraft is traveling fast enough, it achieves a state of continuous free-fall around that body. Thus, it is held in 'orbit' by a fine balance of motion and gravity until it either accelerates further to raise its orbit and achieve escape velocity, or decelerates to a lower orbit to begin the re-entry and decent to a landing.

A note on Gemini designations
The Gemini missions have been identified in different ways, including those which flew solo without an Atlas-Agena target and those which included an Atlas-Agena launch. Normally, the launch vehicle was also added to the description, thus: Gemini-Titan (abbreviated as GT-#) or with an Agena vehicle as Gemini-Titan-Agena (abbreviated as GTA-#) The flight numbers were often designated in Arabic numerals as Gemini 1 through 12, although NASA documentation of the time and the official accounts of the program used the Roman numerals I, II, III, IV, V, VII, VI, VIII, IX, X, XI and XII. To complicate this further, the original Gemini 6 and 9 missions were rescheduled and adopted the designations Gemini 6A (VI-A) and Gemini 9A (IX-A) when they flew. In these books, for clarity, the Arabic identification system has been adopted in most instances.

AC	Alternating Current
ACE	Attitude Control Electronics
ACME	Attitude Control Maneuver Electronics
AFB	Air Force Base
AMU	Astronaut Maneuvering Unit
ANT	Antigua (secondary tracking station)
ASC	Ascension Island (secondary tracking station)
BDA	Bermuda (PRIMARY tracking station)
BECO	Booster Engine Cut-Off
BEF	Blunt End Forward (rear of the spacecraft facing the direction of flight)
CAL	Point Arguello, California (PRIMARY tracking station)
Cape	Cape Kennedy/Canaveral, Florida
Capcom	Capsule Communicator

CG	Center of Gravity
CNV	Canaveral (Cape Kennedy) Launch Control Center, Florida (PRIMARY tracking station)
COSPAR	Committee on Space Research (International)
CRO	Carnarvon, Australia (PRIMARY tracking station)
CSQ	*Costal Sentry Quebec* (PRIMARY tracking ship)
CTN	Canton Island (secondary tracking station)
CYI	Grand Canary (PRIMARY tracking station)
DAS	Data Acquisition System
DC	Direct Current
DCS	Digital Command System
DEI	Design Engineering Inspection
DoD	Department of Defense
ECS	Environmental Control System
EGL	Eglin Field, Florida (secondary tracking station)
ETR	Eastern Test Range, Florida
EVA	Extra-Vehicular Activity (or ‘spacewalk’)
FAI	Fédération Aéronautique International
FDI	Flight Director Indicator
FIDO	Flight Dynamics Officer
g	Gravity (*g*) force
G&C	Guidance and Control
GBI	Grand Bahamas Island (secondary tracking station)
GET	Ground Elapsed Time
GLV	Gemini Launch Vehicle (Titan II)
GMT	Greenwich Mean Time (UK: Universal or ‘Zulu’ Time)
GPO	Gemini Project Office
GSFC	Goddard Space Flight Center (secondary tracking station)
GT	Gemini-Titan (launch vehicle)
GTA	Gemini-Titan-Agena (launch vehicle)
GTK	Grand Turk Island (secondary tracking station)
GYM	Guaymas, Mexico (PRIMARY tracking station)
HAW	Kauai, Hawaii (PRIMARY tracking station)
HF	High Frequency
HHMU	Hand-Held Maneuvering Unit
HOU	Mission Control Center, MSC, Houston, Texas (PRIMARY tracking station)
IGS	Inertial Guidance System
IMU	Inertial Measurement Unit
IVI	Incremental Velocity Indicator

KNO	Kano, Nigeria, Africa (secondary tracking station)
LC	Launch Complex
LTV	Ling-Temco-Vought
MA	Mercury-Atlas
Max Q	Maximum Dynamic Pressure
MCC	Mission Control Center (HOU/Houston)
MDF	Mild Detonating Fuse
MDS	Malfunction Detection System
MECO	Main Engine Cut Off
MET	Mission Evaluation Team
MISTRAM	MISsile TRAcking Measurements
MOCR	Mission Operations Control Room
MOL	Manned Orbiting Laboratory (USAF)
MR	Mercury-Redstone
MSC	Manned Spacecraft Center (Houston, Texas)
MSFN	Manned Space Flight Network
MSU	Michigan State University
MTR	Module Test Review
MUC	Perth, Australia (secondary tracking station) – used the same call-sign as former Mercury station at Muchea, Australia
NADC	Naval Air Development Center
NASA	National Aeronautics and Space Administration
NASCOM	NASA COMmunications
OAMS	Orbital Attitude and Maneuvering System
PAO	Public Affairs Officer
PCM	Pulse Code Modulation
POISE	Panel On In-Flight Scientific Experiments
PRE	Pretoria, South Africa (secondary tracking station)
R&R	Rendezvous and Recovery
RCS	Re-entry Control System
RGS	Radio Guidance System
RKV	*Rose Knot Victor* (PRIMARY tracking ship)
RR	Roll Rate
RRS	Retrograde Rocket System
RSS	Reactant Supply System
RTK	*Range Tracker* (secondary tracking ship)
SECO	Second stage Engine Cut-Off
SEF	Small End Forward (nose of spacecraft facing the direction of flight)

SEP	SEParation (from Titan booster)
SFRRB	Spacecraft Flight Readiness Review Board
SPADATS	SPAce Detection And Tracking System (USAF)
SST	Spacecraft Systems Tests
STG	Space Task Group
T	Terminal countdown either before (T-/Minus/or down) or after (T+/plus/or up) lift-off
TAN	Tananarive, former Malagasy Republic now Madagascar (secondary tracking station)
TCA	Thrust Chamber Assembly
TEX	Corpus Christi, Texas (PRIMARY tracking station)
UHF	Ultra-High Frequency
VCM	Ventilation Control Module
VTR	Voice Tape Recorder
WHS	White Sands, New Mexico, (secondary tracking station)
WLP	Wallops Island, Virginia (secondary tracking station)
WOM	Woomera, Australia (secondary tracking station)

Prologue

Taking a Walk in Space

Hatch covers are opened…
The spacemen step outside.
The world about them is silent,
with the black vault of infinity around them.
Stars, clear and untwinkling, brighten the somber veil.
Frank Ross Jr., Space Ships and Space Travel, 1956

The highly technical and physical activity of 'stepping outside' a spacecraft has always been fraught with danger and risk but, as portrayed in the lines above, it has also been the source for vivid imagination. For over 50 years, *Taking a Walk in Space* has captured the imagination, excitement and awe not only of those who conduct the activity, but also those who follow the exploits of the space explorers as they 'crack the hatch' and step outside into the void. Without doubt, the opportunity to perform a spacewalk, officially termed Extra-Vehicular Activity or EVA, ranks high on the bucket list of any space explorer.

Today, EVA is a fairly regular occurrence on the International Space Station. After thirteen years of assembling the bulk of the station, supported by teams of EVA astronauts and cosmonauts, an extensive program of station maintenance and repair is now being carried out regularly in orbit. That capability was honed during the American Shuttle program and by the crews of the Skylab (U.S.), Salyut and Mir (Russia) space stations over three decades, beginning in 1973. The ability to work in open space outside the protective cocoon of a spacecraft or space station is an important and integral element of space exploration, and will continue to be so for decades to come.

The history books rightly marvel at the achievements of Apollo and the series of moonwalks between 1969 and 1972, but the true genesis of operational EVA can be found in the series of EVAs conducted by a handful of astronauts in 1965 and 1966 under the Gemini program. These ten missions were a stepping stone approach to enable Apollo to reach the Moon successfully, but also provided a wealth of experience, a cadre of superbly prepared workers, technicians, engineers, controllers, astronauts and managers, and a range of answers to questions and lessons to learn. Some of these were easy to recognize and apply, others were not.

The mission of Gemini 4 offered a real opportunity to test the early theories of rendezvous and proximity operations, an extended-duration spaceflight far longer than the 24 hours Mercury was capable of, and the first inevitable step outside on EVA. It is this last achievement that Gemini 4 is mostly remembered for, though the others should not be quickly overlooked as they contributed to a greater understanding of orbital ballet and long-duration spaceflight that has since been applied to Apollo, the Shuttle and ISS, and has been performed by the Russians and, more recently, the Chinese. For this volume, the focus is upon the EVA, as long-duration spaceflight and rendezvous and docking apply more aptly to later volumes in this series.

The suggestion of 'dancing around an airlock' was first seriously proposed by the Russian 'Father of Cosmonautics', teacher Konstantin Tsiolkovsky, whose 1933 paper *Album of Space Travel* included an image of a space-suited astronaut exiting an airlock for access to open space, similar to the real achievement of cosmonaut Alexei Leonov on Voskhod 2 some 32 years later. Then, as recounted in this author's earlier work, *Walking in Space* [Springer/Praxis 2004], the historical development of what we call EVA took a journey through science fiction and theoretical studies to more formal studies and proposals. During the 1950s, there were serious illustrated articles, books and papers exploring the physiological aspects of an astronaut leaving their spacecraft to work outside. These illustrations often portrayed heavy construction work, with teams of space-suited astronauts welding, bolting and fabricating huge space stations or complexes high above the Earth. They explored challenges such as the dynamics of handling such massive pieces of hardware safely and efficiently, with the workers able to survive outside for more than a few minutes in adequate garments and life support systems that protected them from radiation and shaded their eyes from harmful solar rays, yet illuminated work areas in periods of orbital darkness.

In the early 1960s, the conditions were right to look seriously at opening the door of a spacecraft to begin operations outside the vehicle. Just a few short years after man first entered space, it was still a risky and daring proposal. The inclusion of EVA was an early objective of Gemini, but although it would be useful experience prior to Apollo, a walk in space would not have too much in common with walking in the reduced gravity environment of the Moon. Gemini provided experience of working in a vacuum, in a pressure garment and with tools and equipment, but the physical challenges on Gemini were more focused upon the upper body. For Apollo, the workloads on the lower limbs would have to be considered in physically walking over the undulating lunar surface. There were training aids available to simulate this as far as possible here on Earth; a selection of fixtures and rigs to simulate lunar EVA and similar facilities for practicing Gemini EVAs. At this stage though, in 1965, the benefits of using large water pools to simulate long periods of EVA in free space had yet to be realized, and the technique would not be applied until almost at the end of the Gemini program. Ed White's successful excursion on Gemini 4 was an important early step in mastering the challenges of EVA, but its brevity also masked some of the difficulties of working in free space that the later Gemini EVAs astronauts would encounter.

Without doubt, Gemini 4 was a landmark mission for the Americans. They had indeed caught up with the Soviets in terms of technology with Gemini and in fact, without knowing it at the time, had actually moved ahead of them. Gemini 4 was therefore a turning point both for the race to the Moon and for America's efforts in mastering the techniques of human spaceflight. Clearly there was much more to accomplish, but the mission would provide a strong foundation for further advancements in EVA, rendezvous and docking, long-duration spaceflight and operational activities for crews during longer missions.

Looking back from the perspective of 50 years or so later, Gemini 4 was clearly a game-changer, though in the spring of 1965 this was by no means clear. Indeed, there was still uncertainty over whether to perform a simpler stand-up EVA or a full exit, and there was a conflict before the mission between what was hoped it could accomplish and what actually might be possible. The contrast to the situation post-flight was stark. Suddenly, by the time Gemini 4 splashed down, the American astronauts were demonstrating a maturity of spaceflight that many had not thought possible. Gemini was delivering, the Moon looked closer and NASA was riding high on the success. This was the start of the golden era of NASA and American human spaceflight and Gemini 4 was the catalyst from which it began.

1

Stepping into the void

"To place one's feet on the soil of asteroids,
To lift a stone from the Moon with your hand,
Construct moving stations in ether space,
To observe Mars [or] descend to its surface,
A great new era [for a] more intensive study of the heavens."
Konstantin Tsiolkovsky, *Beyond Planet Earth*, 1920.

Almost a century ago, dreams of developing the technique of leaving the spacecraft to perform useful work in open space were inspired by the Soviet 'Father of Cosmonautics', Konstantin Tsiolkovsky. Nearly fifty years later, that same goal was the genesis for undertaking extensive experiments to learn to work in open space, not only on the surface of the Moon but also in low Earth orbit. Half a century after Gemini, that same desire remains, continuing to expand on the pioneering work conducted during that program and the knowledge and capability acquired since then, to support a renewed interest not only in the exploration and exploitation of near-Earth space, but also a return to the Moon, exploration of Mars and investigations of our nearest asteroids. The theories were derived by Tsiolkovsky and others, and the historic spacewalk of Alexei Leonov in March 1965 proved that the concept was possible, but it would be the Gemini missions that would truly encounter and begin to understand the significant experiences, frustrations and difficulties of performing useful work outside a spacecraft. That journey would begin during the first orbits of Gemini 4, but the path which led to Ed White opening the hatch and stepping into void would not be a straightforward one.

D. J. Shayler, *GEMINI 4*, Springer Praxis Books,
https://doi.org/10.1007/978-3-319-76675-1_1

EVOLUTION OF A SPACEWALK

As early as March 1961, NASA considered that any experiment involving leaving the spacecraft and performing an activity in the vacuum of space would, for safety reasons, require at least two astronauts, even if only one of them actually exited the vehicle. Clearly, this meant that the one-man Mercury capsule could not support such an activity. Not only would the spacecraft have to be enlarged to accommodate a crew of two, but new types of spacesuit, life support system connections, a hatch capable of being opened and closed in a vacuum and a cabin capable of re-pressurization would also need to be developed. From just these relatively basic requirements, it soon became clear that the proposed Mercury Mark II would be the most suitable vehicle to support such early activities external to the spacecraft. These activities have become widely referred to as 'spacewalking', but are more officially termed Extra-Vehicular Activity (EVA, meaning 'activity outside a vehicle', as opposed to Intra-Vehicular Activity, or IVA, 'activity inside a vehicle') [1].

Clear and defined objectives for the next American manned space program after Mercury, including EVA, formed a strong case early on for Gemini, which emerged from Mercury Mark II and was designed with the intention of supporting all such requirements. One of the most important decisions in the redesign of Gemini from Mercury Mark II was in the new configuration of the crew hatches, which would make it easier for the astronaut to enter the spacecraft on the launch pad and leave it at the end of the mission. The hatches were also critical to the planned inclusion of ejection seats that would be used in case of an emergency, such as a launch abort at low altitudes or ejection from the spacecraft due to parachute failure during the latter states of recovery. A third benefit, though no one voiced it very strongly at the time, was the possibility of opening the hatch in orbit, allowing one of the crew to exit and work outside for a short period.

With the Gemini program formally approved at the end of 1961, work on devising an operational EVA system continued concurrently with development of the spacecraft. During the latter half of 1962, NASA's Life Systems Division produced a report on work that had been conducted to evaluate the basic equipment necessary to protect astronauts outside the vehicle. This included the design and workability of pressure suits, ventilation, thermal protection, potential maneuvering units and insulation.

By February 1963, the Manned Spacecraft Center's (MSC) Crew Systems Division had established guidelines for the possibility of EVA from Gemini and requested that prime contractor, the McDonnell Aircraft Company (MAC, later McDonnell-Douglas), investigate the basic requirements for conducting both a 'simple' EVA (in which a single astronaut would open the hatch and 'stand up' on his seat, with only his head and upper torso extending out of the spacecraft) and a more complicated, full-exit EVA from the Gemini spacecraft. The following

Ed White on EVA June 3, 1965.

month, during a special meeting of 15 key representatives from the Gemini Program Office, the Flight Crew Operations Directorate, the Crew Systems Division (including James W. McBarron and James V. Correale) and the Astronaut Office (astronaut John Young) at the MSC on March 22 to establish guidelines for Gemini EVA, approval was given for the proposed EVA requirements [2]. These included:

- For the EVA suit, the current Gemini single-wall pressure vessel concept would be used, and "a loose fitting thermal covering will be added if required," fabricated from materials available at that time. There were study contracts in place, together with MSC in-house capabilities, that were deemed sufficient to obtain the necessary thermal data, including any heater requirements. A sun visor-type device was to be added to the helmet to protect the eyes from heat and glare, with local protection for the gloves and boots added as required.
- No additional instrumentation was required, based upon an assumption that the first excursion would be a preliminary *stand-up* EVA using the spacecraft's biomedical instrumentation.
- The spacecraft's redundant communication (12 wires) system would be employed during the EVA.
- A tether was to be provided for safety at all times, the length of which would be sufficient to allow translation to the Adapter. It was only considered as a means of positively attaching the astronaut to the spacecraft, as other equipment would be provided for "maneuvering and maintaining stability."
- Further testing was to be completed before an emergency oxygen system was provided.

The proposal featured a 30-minute EVA period, with the lone astronaut remaining tethered or attached to the spacecraft at all times for added safety. McDonnell was also asked to include the capability for a (single) crewmember to leave the cabin on *each* mission from spacecraft number 4 onwards. These guidelines suggested that the first EVA from Gemini would be a 'stand-up' EVA, presumably to practice opening and closing the hatch and operating the suit and systems prior to a full exit. They also indicated that provision would be made to allow the astronaut on a full-exit EVA to translate to the rear of the spacecraft, including "ingress to the Adapter." This was a bold plan, given that the EVA astronaut would be out of line of sight of the Command Pilot.

In May 1963, the David Clark Company was awarded the prime contract for the Gemini EVA suit. By the end of that year, the MSC had received and evaluated proposals for an EVA life support package, with the Garrett Corporation's design selected for production.

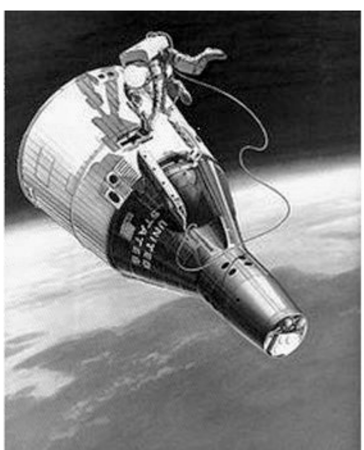
GEMINI EVA PLAN

To assist the astronauts with their training for future Gemini missions, McDonnell published the Project Gemini Familiarization Manual. This was divided into sections, covering a description of the intended mission in Earth orbit and details of the major structural assemblies, the crew compartment and the major sub systems. To summarize the much larger document, a slimmer Gemini Familiarization Package was issued in August 1962 by the Crew Engineering branch of the MSC Flight Crew Operations Division. In the introduction, the program's objectives and roles of the two-man crew were explained, together with a comparison between Mercury and Gemini [3].

One of the program objectives listed in the document was to "determine man's capabilities in space during extended missions [up to 14 days] in Earth orbit." Under Crew Tasks, the astronauts were to be "used as a required integral part of Gemini, [to ensure that] increased crew usage [for] onboard command and control wherever logical is implemented in the program."

The Pilot-Commander (subsequently revised to Command Pilot) would have primary control for operating the spacecraft during all phases of flight. Meanwhile the second astronaut, initially termed the Co-Pilot/Systems Engineer (later simplified to Pilot), would provide backup to the Pilot-Commander and would be responsible for managing the operation of both the spacecraft and, on later docking missions, the systems in the Agena target vehicle.

One of the major differences between Gemini and Mercury was the planned capability for the crew to leave the Gemini spacecraft while in orbit. While EVA was intended to be part of the overall program, however, specific experiments had yet to be determined, and indeed the requirements for a suitable pressure suit had still to be defined. But right from the early stages, the design of the Gemini hatch featured the capability for it to be opened by the crew in orbit, allowing for the possibility of conducting an EVA.



Early artist's impression of an astronaut conducting EVA from a Gemini spacecraft [original of poor quality].